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Interpretive summary

Trained-user opinion about Welfare Quality® measures and integrated scoring of dairy cattle welfare. By de Graaf et al. Overall welfare assessments can be used for communication with consumers (labelling), as incentive for welfare improvements and as regulative target. Such assessments should be valid, reliable and balance the relative importance of various welfare measures. The Welfare Quality® (WQ) approach is one of the most well-known methods for overall welfare assessment. However, the present study shows that the WQ integration method should be revised if it is to correspond with the opinions of trained users of the WQ protocol for dairy cattle.

Trained-user opinion about Welfare Quality® measures and integrated scoring of dairy cattle welfare

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ABSTRACT

The Welfare Quality® (WQ) protocol for on-farm dairy cattle welfare assessment describes 27 measures and a step-wise method to integrate values for these measures into 12 criteria scores, grouped further into four principle scores and finally into an overall welfare categorization with four levels. We conducted an online survey to examine whether trained users' opinions of the WQ protocol for dairy cattle correspond with the integrated scores (criteria, principles and overall categorization) calculated according to the WQ protocol. First, the trained users' scores (n = 8 - 15) for reliability, validity and their ranking of the importance of all measures for herd welfare were compared to the degree of actual impact of these measures on the WQ integrated scores. Logistic regression was applied to identify the measures that affected the WQ overall welfare categorization into the 'not classified' or 'enhanced' categories for a database of 491 European herds. The smallest multivariate model whilst maintaining the highest % of both sensitivity and specificity for the 'enhanced' category contained six measures, the model for not-classified contained four measures. Some of the measures that were ranked as least important by trained users (e.g. measures relating to drinkers) had the highest influence on the WQ overall welfare categorization. Conversely, measures rated as most important by the trained users (e.g. lameness and mortality) had a lower impact on the WQ overall category. In addition, trained users were asked to allocate

‘criterion’ and ‘overall’ welfare scores to seven focal herds selected from the database (n = 491 herds). Data on all WQ measures for these focal herds relative to all other herds in the database were provided. The degree to which expert scores corresponded to each other, the systematic difference and the correspondence between median trained-user opinion and the WQ criterion scores were then tested. The level of correspondence between expert scoring vs. WQ scoring for 6 of the 12 criteria and for the overall welfare score was low. The WQ scores of the protocol for dairy cattle thus lacked correspondence with trained users on the importance of several welfare measures.

Keywords: animal welfare, welfare assessment, trained-user opinion, Welfare Quality®

INTRODUCTION

Assessing animal welfare is a highly complex task. Animal welfare is a multidimensional concept, which calls for a multi-criteria assessment using a multitude of welfare-indicators (Mason and Mendl 1993; Fraser et al., 1997). To express the overall welfare status of a group of (farm) animals in one score or index, indicator data should be integrated which requires interpretation and balancing. The lack of a ‘gold standard’ for animal welfare assessment (i.e. there is no standardized and commonly agreed-on method for assessing the overall welfare status of a group of farm animals) implies that some degree of subjectivity is inevitable when weighting different measures (Spoolder et al., 2003). To be widely accepted, an overall welfare index ought to correspond with society’s concept of animal welfare and with the opinion of experts, i.e. people who are seen by society to have adequate knowledge and expertise about animal welfare. However, opinions on the concept of animal welfare may differ between and even within experts and society. For example, producers tend to highlight basic health and functioning of farm animals while non-producers tend to emphasize the need for a natural living environment of farm animals (reviewed by Sørensen and Fraser, 2010). It

74 can be argued that for people without expertise in dairy cattle welfare and the specific welfare
75 measures involved, it is too difficult to adequately balance the importance of different welfare
76 measures. It has been shown that providing detailed information about on-farm collection
77 methods of welfare measures, significantly influences the relative weights they are given by
78 experts (Rodenburg et al., 2008). Therefore, the current study elicited experienced animal
79 scientists on the specific welfare measures involved only.
80 To date, the Welfare Quality® (WQ) protocols are most likely the most renowned and
81 comprehensive method for overall welfare assessment of different farm animal species
82 (chickens, pigs and cattle) (Welfare Quality, 2009). Unlike some other welfare assessment
83 protocols, WQ relies predominantly on animal-based measures. Resource-based and
84 management-based measures, in contrast, mostly reflect risk factors for welfare impairments
85 instead of directly measuring welfare (Blokhuis et al., 2003; 2010). The WQ protocols are
86 based on four main welfare principles ('good feeding', 'good housing', 'good health' and
87 'appropriate behavior') which are split into 12 independent welfare criteria (Table 1). Various
88 welfare measures (n = 27 for dairy cows) were selected by animal scientist to assess these
89 welfare criteria, based on validity, reliability and feasibility to perform on-farm. The WQ
90 protocol describes three steps to integrate these welfare measures into an overall final welfare
91 category. Methods of integration aim to be widely acceptable by society and are therefore
92 based upon expert opinion of social and animal scientists and stakeholders (Botreau et al.,
93 2007), depending on the integration step. For interpretation of measures into criteria scores,
94 animal scientists were consulted (n = 6) who were involved in the choice and development of
95 the WQ measures (Botreau et al., 2008). They were asked to score several situations which
96 could occur on-farm per criterion (e.g. for integument alterations within the criterion 'absence
97 of injuries', experts were asked to score 11 hypothetical farms with varying prevalence of
98 hairless patches, wounds and swellings). Calculation of criterion scores is based on expert

scoring. For aggregation from criteria to principle scores, social scientists were involved as well, using a similar approach. For the final step, several scenarios for reference profiles were developed to aggregate principle scores into an overall category. These scenarios were tested for 69 European dairy farms (Austrian, German and Italian) to firstly compare their ability to discriminate between farms. Secondly, stakeholders were consulted to assess which scenario was most appropriate and thirdly, the degree to which each scenario matched with the general impression of observers for 44/69 dairy farms was assessed. The four overall categories ('excellent', 'enhanced', 'acceptable' or 'not classified' (Welfare Quality®, 2009)) were constructed to reflect both the multi-dimensional nature of welfare and the relative importance of the various welfare measures using mathematical operators which limit the amount of compensation which may occur between welfare measures, i.e. when a combination of positive scores compensate for one negative score (Botreau et al., 2009).

Recent critical evaluations of the WQ integration methods indicate that in the dairy cattle protocol a few resource-based measures appear to have a disproportionately large influence on integrated scores (Heath et al., 2014; de Vries et al., 2014). For example, the measures for the criterion 'absence of prolonged thirst' (i.e. number, adequate functioning and cleanliness of drinkers) have a relatively large influence on integrated scores, although they are criticized for their low or undocumented validity (Knierim and Winckler, 2009; de Vries et al., 2013; de Jong et al., 2016; Tuyttens et al., 2014). In contrast, some of the most pressing welfare problems for dairy cattle as highlighted by epidemiological studies (de Boyer des Roches et al, 2014; Main et al, 2003; Whay et al, 2003) and assessed by experts (i.e. mortality, lameness and mastitis, Lievaart and Noordhuizen, 2011; Nielsen et al., 2014; Whay et al., 2003), had a smaller influence on overall welfare categorization (de Vries et al., 2013; Heath et al., 2014; Buijs et al., 2016) These findings point towards potential discrepancies between the welfare assessment in dairy cattle of certain welfare experts and the WQ scores.

The WQ protocols were designed with the intention of modifying and updating assessment methods according to advances in animal welfare science. Currently, a large group of researchers has become familiar with the protocol and many farm visits have been performed by these researchers (further referred to as 'trained users'), allowing for a thorough evaluation of the impact which measures have on overall welfare categorization. Therefore, analyzing the correspondence between WQ integrated scores and the opinion of such trained users has now become feasible. Hence, the objective of the current study was to analyze correspondence between welfare assessment by trained users and the WQ scores (criterion and overall welfare category). We performed this by examining whether measures which impact WQ categorization most are also those which are deemed most important by trained users.

MATERIALS AND METHODS

WQ Protocol

A brief description of the WQ protocol for on-farm dairy cattle welfare assessment is presented below; the full protocol can be found at http://www.welfarequalitynetwork.net/. In short, the protocol describes 27 on-farm welfare measures (Table 1) that are subsequently integrated in a 3-step process to arrive at an overall welfare category. First, 27 welfare measures of various scales are combined into scores for 12 welfare criteria on a scale of 0 (worst) – 100 (best) (Table 1), using various aggregation methods (for details see Welfare Quality®, 2009). Second, criteria are integrated into scores for four welfare principles using Choquet integrals, algorithmic operators which ensure that a poor score cannot be fully compensated by a better score in another criterion (Botreau et al., 2008). Principle scores can range from 0 (worst) to 100 (best). The third and final integration step is an outranking procedure from principle scores, arriving at an overall welfare category. Dairy welfare in a

herd is considered ‘excellent’ when that herd scores >50 for each principle and >75 on two of them. When a herd scores >15 on each principle and >50 on at least two of them, it is classified as ‘enhanced’. ‘Acceptable’ herds score >5 for all principles and >15 for at least three principles. Herds that do not reach the thresholds for the category ‘acceptable’ are considered ‘not classified’. These reference profiles for overall welfare categorization were based on data from 69 herd assessments in the European Union (Botreau et al., 2009).

<Table 1>

Collating WQ Data

Datasets of assessments using the WQ protocol for on-farm dairy cattle welfare were collated from seven European research institutes. Data from 10 countries (Macedonia, The Netherlands, France, Belgium, Scotland, Denmark, Romania, Northern Ireland, Spain and Austria) and 491 herds were used. The collected samples were selected to be representative for 1) small scale dairy herds in Macedonia (n = 12); 2) non-organic and non-tie stall dairy herds in The Netherlands (n = 60) and France (n = 128); 3) random herds with individual Somatic Cell Count data available (SCC, to be able to calculate WQ scores) in Belgium (n = 140), Scotland (n = 16) and Denmark (n = 42); 4) typical herds for the regional low-input herding systems in Romania, Northern Ireland and Spain (n = 30); and 5) loose housed dairy herds with at least 20 cows in Austria (n = 65). Integrated WQ scores were calculated from raw data using a custom-made integration procedure programmed in R 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria). The R integration program is available on request. The resulting welfare scores were in agreement with the INRA WAFA webtool (http://www1.clermont.inra.fr/wq/), in which WQ measure scores can be entered (for dairy cows, fattening cattle, growing pigs and broilers), and WQ criteria, principle and categorization scores are provided.

Survey

The survey was sent to 31 trained users, partially completed by 14 - 15 (depending on the question) and totally completed by 8 trained users. The survey was sent to animal welfare scientists which the co-authors knew to be experienced in the WQ assessment protocol for dairy cow welfare. These trained users were in turn asked to provide contact details of any additional animal welfare scientists which would be suitable (trained to use the WQ protocol). All trained users who filled out the survey, were not involved in creating the survey. All trained users had experience with the WQ protocol for dairy cattle (i.e. were trained to perform the WQ protocol for dairy cattle and had performed on-farm WQ assessment of dairy herds), were animal scientists and had authored at least 1 peer-reviewed scientific paper about dairy cattle welfare involving the WQ protocol. Trained users were all European and a total of 8 different nationalities was represented (British, Spanish, Macedonian, Dutch, Finnish, Austrian, German and French). Trained users were surveyed on their judgement of the reliability, validity and importance of all WQ measures. In questions based on data from the WQ EU database, they were asked to score the farms for each WQ criteria and to assign an overall welfare score.

Reliability, Validity and Ranking of all WQ Measures for Dairy Cattle. The trained users were asked to indicate how acceptable they judged the reliability and validity of all measures using a tagged visual analogue scale from 0 to 100. Tags were 'not acceptable (<25)', 'just acceptable (25 – 50)', 'acceptable (50 – 75)', and 'very acceptable (75 – 100)'. 'Reliability' was defined in the survey as 'a combination of inter-observer, intra-observer and test-retest reliability'. 'Validity' was defined as 'the measure measures what it is supposed to'. Trained users were then asked to rank all WQ measures according to importance for the overall welfare status of a herd of dairy cattle from 1 (most important) – 27 (least important).

196 It was mentioned that for ranking, (inter alia) reliability, validity, perceived relevance and
197 prevalence may be considered.

198 ***Expert scoring based on all WQ measurements.*** The trained users were then asked to
199 score overall welfare based on all measures from the WQ protocol. They were shown one
200 figure with box plots for all measures (part of the figure for one criterion: Figure 1). These
201 showed the same herds as in the first figure using the same colored triangles. Trained users
202 were asked to score overall welfare of 7 focal herds using a 0-100 tagged visual analogue
203 scale, with the tags 'not classified' (< 20), 'acceptable' (20 – 55), 'enhanced' (55- 80) and
204 'excellent' (>80). For this purpose, we randomly selected five herds from the 'acceptable'
205 welfare category and two herds from the 'enhanced' category out of the entire dataset. This
206 reflects the distribution of the dataset in which 1.8% of the herds were categorized as 'not
207 classified' (9 herds), 62.7% as 'acceptable' (308 herds), 35.4% as 'enhanced' (174 herds) and
208 none as 'excellent'.

209 <Figure 1>

210 ***Comparing WQ Criteria Scores Using Trained-user Opinion***. To assess the degree to
211 which integrated WQ criteria scores correspond to trained-user opinion, the trained users were
212 shown graphs of all measures per criterion separately, showing the distribution of all herds in
213 the database (example of one criterion: Figure 2, data shown in Table 2). The 'focus herds'
214 were highlighted using triangles in different colors, and tables stated the data for each.
215 Trained users were asked to score the herds for all 11 criteria (excluding the criterion 'thermal
216 comfort', as this is not measured on-farm for dairy cattle) on a 0-100 tagged visual analogue
217 scale using the tags 'not classified (< 20)', 'acceptable (20 – 55)', 'enhanced (55- 80)' and
218 'excellent (>80)'.

219 <Figure 2>

220 ***Statistical analysis***

221 The statistical analysis was performed in R 3.2.2 (R Foundation for Statistical Computing,
222 Vienna, Austria). The analyzed data (except overall welfare categorization) were considered
223 to be sufficiently normally distributed, based on the graphical evaluation (histogram and QQ-
224 plot) of the residuals.

225 ***Reliability, Validity and Ranking of all WQ Measures for Dairy Cattle.*** To examine the
226 influence of median reliability and validity scores and their interaction on median ranking of
227 all measures, we used a linear mixed regression model with reliability and validity scores as
228 independent variables, and importance rank as dependent variable. A random effect for expert
229 was included in the model to account for the repeated measures.

230 ***Predicting Overall Welfare Categorization Using WQ Measures***. To analyze which
231 measures affected the WQ overall categorization both into the lowest (not classified) and the
232 highest (enhanced, as no farms were categorized as excellent) categories, welfare categories
233 of the entire European dataset (n = 491) were divided into two binary variables (1=enhanced,
234 0=other for variable 1; and 1=not classified, 0=other for variable 2). Logistic regression was
235 used to identify measures that affected overall categorization both univariate and multivariate.
236 For the latter, a model was built using stepwise forward selection, retaining measures with a P
237 < 0.05 while maintaining the highest R2. Collinearity was checked for measures used within
238 the models. Model outcome was assessed by calculating specificity and sensitivity using the
239 following formulae:

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} \quad \text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

240 Where TN = true negatives, FP = false positives, TP = true positives and FN = false
241 negatives. Negatives were those farms categorized as 'other' and positives were those farms
242 categorized as either 'enhanced' for the first binary variable or 'not classified' for the second.

Comparing WQ Criteria Scores with Trained-user Opinion. To assess the systematic difference between the median trained-user opinion score and the WQ criteria scores for each focal herd (n = 7), a paired t-test was performed. To model the correspondence of median scores allocated by the trained users and the WQ criteria scores, a linear model was fitted and the coefficient of determination was calculated. Additionally, the intra-class correlation coefficient (ICC) was calculated to assess the degree of coherence between individual trained-user opinions.

RESULTS

Perceived Reliability, Validity and Ranking of WQ Measures

Median validity and reliability scores for all measures were 'acceptable' to 'very acceptable' (i.e. median scores > 50, Table 3). Nevertheless, there was variation in median scores for the various measures, ranging from 60 to 100 and from 50 to 90 for reliability and validity respectively. Highest median ranking was attached to 'lameness score' (rank 2), 'body condition score' (4), 'mortality rate' (7) and 'integument alterations' (7). 'Lameness score' and 'integument alternations' received the highest median validity scores (89 and 90, respectively), along with 'lying outside the lying area' (89) and 'tail docking method' (88). 'Tied versus loose housing' (100), measures of drinker space ('Centimeters of trough per cow (minimum 6 cm), number of water bowls per cow (minimum 0.10) and at least two drinkers available for each cow' (93) and 'water flow' (90) received the highest median reliability scores. The measure 'Qualitative Behavior Assessment' (QBA) was given the worst median importance rank (22), the lowest median reliability score (60), and was among the lowest median validity scores (57). Measures of drinker space was given the lowest median validity score (50). 'Water flow' was among the lowest ranking measures in terms of importance (20) and among the lowest median validity scores (60) as well. Highest variation in reliability

scores between trained users (SD) was found for QBA (32), and lowest variation for 'Body condition score'(10). For validity scores, highest variation between trained users was found for validity scores of 'water flow'(28) and lowest for integument alterations (8). For ranking, scores for 'Tail docking method', 'Head butts and displacements' and 'Avoidance distance test' (9) were most variable and scores for 'Mortality' and 'Integument alterations' were least variable (4).

<Table 3>

The importance rank of the measure was negatively associated with both the reliability and validity scores, although validity had a somewhat higher estimate (i.e. higher importance as indicated by a lower ranking was associated with higher reliability and validity scores) (P = 0.03 for both, estimates -0.66 and -0.74, respectively, adjusted R^2 = 0.20). A very small but significant interaction was found between reliability and validity scores, where they did not strengthen each other's negative effect on ranking (P = 0.048, estimate = -0.009).

Predicting Overall Welfare Categorization Using WQ Measures

When analyzed univariately, 20 out of 41 measures significantly (P < 0.05) affected overall welfare categorization into the 'enhanced' category (Table 4), and 11 measures significantly affected categorization into the 'not classified' category for the entire European dataset (n = 491).

<Table 4>

The multivariable model that had the fewest variables whilst maintaining the highest % of both sensitivity and specificity (67% and 85%, respectively) for the 'enhanced' category contained the following measures (from most to least influence): 'at least two drinkers/cow', 'water flow', '% of animals lying outside the lying area', 'mean time needed to lie down'

292 ‘drinker cleanliness’, and ‘% of animals with at least one lesion/swelling’ (Table 5). For not-
293 classified, the measures (from most to least influence) ‘at least two drinkers/cow’, ‘number of
294 lean cows’, ‘QBA-index’ and ‘number of displacements/cow/h.’ contributed to the model
295 with fewest variables but the highest sensitivity (44%) and specificity (100%).
296 <Table 5>

297 ***Comparing WQ Overall Welfare Category and Criteria Scores with Trained-user Opinion***
298 For 2 of 5 ‘acceptable’ herds and for 1 of 2 ‘enhanced’ herds, the majority of trained users (n
299 = 8) scored in accordance with WQ (Figure 3). Regarding scores that were not in accordance
300 with WQ, the vast majority were a lower category than the WQ calculation (25 of 29 expert
301 scores). Overall, ICC for overall welfare scores by trained users was 0.5.
302 <Figure 3>
303 The criteria ‘absence of injuries’, ‘absence of pain induced by management procedures’,
304 ‘expression of social behavior’ and ‘good human-animal relationship’ were systematically
305 scored lower by trained users than the WQ score (Table 6). The expert and WQ scores were
306 not significantly related for two criteria: ‘absence of prolonged thirst’ and ‘absence of
307 prolonged hunger’ (Table 6). The correspondence between trained users was insufficient (ICC
308 < 0.6) for two criteria, namely ‘absence of injuries’ and ‘absence of disease’. The number of
309 measures within a criterion tended to be negatively related to ICC (P = 0.06, estimate = -
310 0.04).
311 <Table 6>

312 **DISCUSSION**
313 This study gives insight into the relation of integrated scores of the WQ dairy cattle protocol
314 with trained-user opinion. The specific research design imposes some limitations, but also
315 provides challenges for future research. For example, we chose to only select dairy cattle

316 welfare trained users who were trained users of the WQ dairy cattle protocol. This ensured
317 that trained users had a proper knowledge of the protocol and all measures, but limited the
318 number of possible respondents. The results show discrepancies between trained-user opinion
319 and WQ scores.

320 ***Trained-user Opinion on Ranking, Reliability and Validity of Measures***

321 The measures that the trained users ranked highest in terms of perceived importance for the
322 overall welfare status of a herd (viz. 'lameness score', 'body condition score', 'mortality rate'
323 and 'integument alterations') are in agreement with earlier studies in which dairy cattle
324 welfare trained users were asked to score the importance of welfare measures (Nielsen et al.,
325 2014; Lievaart and Noordhuizen, 2011; Whay et al., 2003). Reliability and validity scores
326 both influenced ranking positively (based on the negative relationship between reliability and
327 validity scores and ranking), but did not positively interact. This means that highest ranked
328 measures in the current study did not necessarily receive the highest validity *and* reliability
329 scores. In addition, although the set-up of this study was such that trained users had to
330 consider validity and reliability before ranking, other (unknown) factors appeared to influence
331 the trained users' opinion on the importance of the various measures for overall herd welfare
332 as well (further supported by the models' low R^2 of 0.20). This was the case for lameness, for
333 example, which was ranked highest for importance although its reliability was among the
334 lowest.
335
336 Overall, QBA was scored among the lowest by the trained users with regard to reliability and
337 validity (although still within the 'acceptable' range) and was ranked lowest on importance
338 for dairy cattle welfare status. The QBA is a method that uses descriptors such as 'frustrated'
339 or 'content', to interpret the behavior and body language of an animal by integrating these
340 details of animal behavior into a qualitative judgment of overall welfare state (Wemelsfelder,

2001; Rousing and Wemelsfelder, 2006; Wemelsfelder, 2007). Inter-observer reliability was tested and deemed acceptable for a QBA method using 'free' descriptors (i.e. not set but determined by observers themselves) and was validated by correlating results to behavioral observations (Rousing and Wemelsfelder, 2006; Napolitano et al., 2012). The fixed-term-method and specific set of descriptors used in the WQ protocol were tested for inter-observer reliability in a study by Bokkers et al., (2012) and judged as not satisfactory by the authors involved (i.e. Kendall's coefficient of concordance < 0.7), whereas Wemelsfelder et al. (2009) reported satisfactory observer agreement in beef, dairy cattle and veal calves of those descriptors. In addition, recently published papers demonstrated internal validity by testing correlation between QBA and other behavioral and physiological measures (Coignard et al., 2014; Phythian et al., 2016; Serrapica et al., 2017).

While some measures scored highest for reliability, they scored lowest for validity, e.g. measures related to the criterion 'absence of prolonged thirst' ('centimeters of trough per cow'), or were ranked lowest on importance for dairy cattle welfare ('water flow'). Criticism expressed in earlier studies for these measures is related to their resource-based nature and the impact these specific measures have on the WQ integrated scores, while preference generally shall be given to animal-based measures (de Vries et al., 2013; Heath et al., 2014; Buijs et al., 2016). Measuring functioning of water points, water provision and water cleanliness refers to assessing a risk for cows being in a certain welfare state and may therefore in some cases not be the most valid measure of an actual welfare state in dairy cattle, in this case due to prolonged thirst. Additionally, to our knowledge, no actual validity testing of the WQ drinker measures has occurred. This could explain the relatively low perceived validity score attached by the trained users to these measures. Further testing of reliability and validity on certain measures is needed, based on the results of the current study and previous research (Knierim

366 and Winckler, 2009). If from such studies it appears that measures are not sufficiently reliable
367 or valid, then research should be performed to propose improved measures.
368
369 The trained users did not always agree on the relative importance for the overall welfare status
370 of dairy herds of different welfare measures (given the high variations in ranking and
371 reliability and validity scores between trained users). This possibly reflects diverging views in
372 what trained users find most important for dairy cattle welfare, as Fraser et al., (1997) showed
373 in his study on animal welfare conceptualization among animal welfare scientists. This
374 indicates that when using trained-user opinion to determine weights for various measures,
375 such variation should be accounted for when selecting the expert panel. Therefore, it is not
376 likely that an overall welfare score will always perfectly reflect an individual trained users'
377 opinion. Methods to achieve more consensus among trained users exist. Examples are
378 deliberative processes using a workshop like performed by Rodenburg et al. (2008), or more
379 complex processes like a 'Delphi' method with multiple rounds of expert elicitation and
380 feedback (Linstone and Turoff, 1975).
381
382 ***Comparison of the measures' impact on overall welfare categorization and trained-user***
383 ***opinion***
384 Compared to previous studies (Heath et al., 2014; Buijs et al., 2016), more measures affected
385 both the 'enhanced' and the 'not classified' categorization in the current study. This is likely
386 due to a larger variation in data in the current study which used a much larger (and diverse, as
387 data was collected in more than one country) database compared to both other studies. To
388 specify, the current sample comprised of 491 herds, as opposed to 92 herds and 22 flocks for
389 Heath et al., (2014) and Buijs et al., (2016) respectively. In accordance with Heath et al.
390 (2014) drinker measures had the biggest influence for both the enhanced and not classified

391 models, while in the current study these received some of the lowest ranks and/or validity
392 scores by the trained users. Additionally, the QBA score which scored lowest overall was
393 among the best predictors for the 'not classified' categorization. By contrast, although there is
394 often little agreement among trained users on importance of various welfare measures, some
395 measures which are regarded as highly important to cattle welfare by certain welfare trained
396 users, did not have a great influence on the overall welfare status categorization. For example,
397 although 'lameness score' and 'mortality rate' contributed to the 'enhanced' categorization in
398 univariate models, they did not when combined into a multivariable model. These results
399 show that the relative influence of measures on WQ integrated scores may not be in
400 accordance with the trained users' opinion of this study. We tested this by comparing expert
401 scoring of WQ criteria and overall welfare with calculated WQ scores.

402 ***Comparing WQ Integrated Scores with Trained-user Opinion***

403 ***Overall welfare category.*** For only three out of the seven herds, the majority of trained
404 users scored in accordance with the WQ overall welfare categorization. The two herds that
405 were scored as 'not classified' by at least half of the trained users (Herds 3 and 7) both scored
406 badly (i.e. relatively high prevalence) on measures that were ranked as highly important by
407 the trained users, namely lesions/swellings and moderately lame cows.

408 Variation between trained users was shown for the overall welfare scoring, given the
409 relatively low ICCs. This was also shown for criteria scores, where ICCs tended to be lower
410 for criteria which contain the most measures. This can indicate that 1) trained users did not
411 agree on their assessment of overall welfare caused by a different view of animal welfare (as
412 mentioned above) and/or 2) some trained users may have had difficulties in aggregating many
413 welfare measures into one overall score. The latter explanation is supported by that fact that
414 six of the 14 trained users who completed the questions on criterion scores, did not complete
415 the question on overall welfare scores.

Criteria scores. The criteria 'absence of injuries', 'absence of pain induced by management procedures', 'expression of social behavior' and 'good human-animal relationship' were systematically scored lower by trained users than the WQ integrated scores. In the WQ protocol, poor scores have more influence on integrated scores than good scores (Buijs et al., 2016). Therefore, lower scores on each of these criteria would have a major effect on principle scores and overall welfare category.

The correspondence between the expert and WQ score for the criterion 'absence of prolonged thirst' was extremely low. The finding that the trained users considered some of these measures of relatively poor validity may partly explain this lack of correspondence. It is a strong indication that trained users of the present study did not agree with the way that the criterion score for 'absence of prolonged thirst' is calculated in the WQ protocol.

Four complementary explanations can be put forward for the poor correspondence between trained users' scores and WQ integrated scores. First, except for the first step of the integration procedure, WQ consulted a much wider group of stakeholders (including animal scientists, social scientists, producers and retailers.) than we did in the current study. These stakeholders' views on the relative impact of the various measures on dairy cattle welfare may differ substantially from those of the trained users in the current study. We opted to limit the current study to trained users only, because it could be argued that they are best qualified to assess overall dairy cattle welfare state and the relative importance of the various WQ measures.

Second, as the protocol was not yet published when stakeholder opinion was elicited during the WQ project, they could not have gained as much experience in performing the various WQ measures as the trained users in this study. It has previously been shown, that detailed information on welfare measures (e.g. practical implications) can significantly

influence relative weight attributed by trained users to these welfare measures (Rodenburg et al., 2008).

Third, there was considerable variation between trained users in the present study regarding importance ranking, although there is no information readily available on the degree of variation between the original WQ trained users. The variation in prioritizing certain aspects of welfare in the current group of trained users could arise from different concepts of animal welfare, like Fraser et al., (2008) described as 'basic health and functioning', 'natural living', and 'affective states'.

Fourth, WQ integration methods likely contribute to differences between trained-user opinion and WQ integrated scores. De Graaf et al., (2016) identified two factors which influence the impact a measure has on the integrated WQ scores, but which seem unintended by the WQ consortium. Namely, 1) the number of integrated measures per criterion or principle, and 2) the various aggregation methods of measures into criteria scores which influence the impact individual measures have on integrated scores. In the present study a low level of correspondence between welfare measures which impact WQ categorization most and which were scored as most important by trained users was found. Also, poor correspondence between trained-user opinion and some criterion scores indicated that this lack of correspondence already starts in the first step of integration.

These findings indicate a lack of correspondence between WQ-welfare scores and trained users' assessment of herd welfare. The opinion of these trained users is the only 'silver standard' we have to validate animal welfare integrated scores, since they are arguably best equipped to assess and quantify the welfare of a given herd. Moreover, these trained users may be considered authorities for animal welfare assessment in society, and it is important that scientists who use this method support it. Future research could focus on determining whether the way trained users assess welfare is in correspondence with other stakeholders'

assessment. Improvements for WQ may be derived from the observed discrepancies between WQ overall welfare assessment and that of the trained users. In some cases, the trained users scored lower than WQ and in other cases (water provision) they were less stringent. Because WQ allocates more weight to low scores this is likely to have a significant impact on the overall assessment. For example, higher criterion-scores for absence of thirst (following our trained users' opinion) would reduce the impact of this criterion on the overall assessment. On the contrary, lameness should be given more impact since our trained users ranked this as highly important.

CONCLUSION

Trained-user opinion on the most and least important measures for the overall welfare status of a herd did not correspond well with the influence of these measures on the WQ overall welfare categorization. Some of the measures that were ranked as least important for herd welfare by trained users (e.g. measures relating to drinkers) had the highest influence on the WQ overall welfare categorization. On the contrary, measures ranked as most important by the trained users (e.g. lameness and mortality) had a lower impact on the WQ overall category. In addition, results indicate poor correspondence between trained users' scoring and 6 of 11 WQ-criteria and the overall welfare category. In both cases, trained users mostly allocated more negative scores, indicating a lower level of welfare. The WQ scores of the protocol for dairy cattle thus lacked correspondence with selected trained users on the importance of several welfare measures.

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619 *Table 1: Principles, the corresponding criteria and measures used in the Welfare Quality®*

620 *assessment protocol for dairy cows*

Principles	Criteria	Measures
Good feeding	Absence of prolonged hunger	Body Condition Score (% very lean animals)
	Absence of prolonged thirst	Availability & cleanliness water
Good housing	Comfort around resting	Lying down duration; collisions during lying down; on edge/outside of lying area; cleanliness
	Thermal comfort	No measure for dairy cattle
	Ease of movement	Free stalls or presence of tethering and exercise
Good health	Absence of injuries	Lameness; integument alterations
	Absence of disease	Respiration/digestive diseases; mastitis; mortality; dystocia, downer cows
	Absence of pain induced by management procedures	Mutilations (dehorning; tail docking; use of anesthetics/analgesics)
Appropriate behavior	Expression of social behavior	Incidence agonistic interactions
	Expression of other behaviors	Access to pasture
	Good human-animal relationship	Avoidance distance at feeding place
	Positive emotional state	Qualitative Behavioral Assessment

621

622 *Table 2: Measure values of each of the seven herds presented to trained users in the survey*

Criteria, measures Herd #	1	2	3	4	5	6	7
Absence of prolonged hunger							
% of lean cows	0	3	17	5	11	3	24
Absence of prolonged thirst							
Number of water bowls/cow	0.5	0.0	0.0	0.0	0.0	0.6	0.05
Trough length/cow (cm)	0.0	7.9	4.7	28.6	9.0	0.0	0.0
Drinker cleanliness	Yes	Yes	No	Yes	Yes	Yes	Yes
At least 2 drinkers/cow	No	Yes	No	No	Yes	No	Yes
Resting comfort							
Mean time needed to lie down (s)	4.6	4.6	7.5	4.1	6.6	5.4	6.8
% of cows colliding with housing equipment	16	15	72	0	37	8	33
% of cows lying outside of lying area	50	11	0	0	0	35	0
% of cows with dirty flanks	34	55	81	14	67	79	70
% of cows with dirty lower legs	57	37	85	38	20	79	100
% cows with a dirty udder	18	21	77	10	42	48	95
Ease of movement							
Loose (L) or tied (T) housing	T	L	L	L	L	T	L
Absence of injuries							
% of moderately lame cows	0	13	88	0	23	0	84
% of severely lame cows	32	0	12	10	17	27	5
% of cows with at least one lesion	7	12	72	28	13	20	68
% of cows with no lesions but at least one hairless patch	98	18	28	38	21	100	32
Absence of disease							
Number of coughs/cow/minute	0.05	0.00	0.13	0.10	0.06	0.17	0.00
% cows with nasal discharge	59	0	0	0	5	18	0
% cows with ocular discharge	0	0	0	0	0	0	0
% cows with hampered respiration	0	0	0	5	0	0	0
% cows with diarrhea	5	0	0	0	0	0	16
% cows with vulvar discharge	0	0	0	0	0	0	3
% cows with SCC[1] > 400.000	8	21	25	0	14	8	12
% cows mortality	5	3	4	0	4	3	4
% calvings with dystocia	0	21	0	0	1	6	3
% downer cows	0	6	0	0	0	6	5
Absence of pain induced by management procedures							
Dehorning method, Thermal (T), Caustic paste (P) or None (N)	T	P	P	N	P	P	T
Use of Analgesics	No	Yes	Yes	No	Yes	No	No
Use of Anesthetics	No	Yes	Yes	No	Yes	No	Yes
Expression of social behavior							
Number of Head butts/cow/15 min.	0.8	4.0	0.7	0.0	0.4	0.4	1.0
Number of Displacements/cow/15	0	1.2	0.1	0.0	0.2	0.0	0.8

min.							
Expression of other normal behavior							
Number of hours on pasture	214	180	0	0	0	214	195
Number of days on pasture	19	9	0	0	0	8	9
Human-animal relationship							
% of cows that could be touched	36	55	59	100	55	44	30
% closer than 50 cm but not touched	11	36	37	0	26	2	35
% between 50 and 1 m	23	9	9	0	11	14	24
% > 1 m	30	0	0	0	9	41	11
Positive emotional state							
QBA[2] score	43	40	8	91	77	66	54

623 [1]Somatic Cell Count

624 [2]Qualitative Behaviour Assessment

625 *Table 3: Median (interquartile range) reliability and validity scores and rankings for each WQ*

626 *measure by trained users*

	Reliability score (n = 15)	Validity score (n = 15)	Ranking (n = 13)
Body condition score	89 (11)	79 (35)	4 (8)
Centimeters of trough per cow (minimum 6 cm), number of water bowls per cow (minimum 0.10) and at least two drinkers available for each cow	93 (15)	50 (34)	13 (6)
Water cleanliness, judged visually	80 (28)	70 (36)	19 (9)
Water flow	90 (33)	60 (40)	20 (15)
Time needed to lie down	75 (38)	78 (21)	9 (7)
Cows colliding with housing	70 (39)	82 (28)	16 (10)
Cows lying outside of lying area	85 (33)	89 (28)	16 (10)
Cleanliness of udders, flanks and lower legs	75 (12)	81 (24)	15 (5)
Tied versus loose housing	100 (6)	84 (28)	11 (13)
Lameness score	69 (36)	89 (11)	2 (2)
Integument alterations	75 (15)	90 (14)	7 (4)
Coughing	69 (44)	75 (35)	19 (13)
Nasal discharge	84 (35)	80 (11)	18 (8)
Ocular discharge	85 (31)	80 (12)	18 (11)
Hampered respiration	88 (36)	86 (12)	21 (12)
Diarrhea	75 (21)	70 (22)	15 (8)
Vulvar discharge	77 (39)	86 (14)	18 (8)
Somatic cell count >400.000	83 (19)	81 (11)	13 (14)
Mortality	79 (47)	81 (16)	7 (6)
Dystocia	79 (37)	80 (17)	13 (10)
Downer cows	79 (47)	81 (16)	15 (14)
Dehorning method	90 (26)	86 (16)	11 (10)
Tail docking method	95 (16)	88 (17)	17 (18)
Head butts and displacements	70 (26)	75 (17)	14 (16)
Access to pasture (number of hours and number of days on pasture)	90 (18)	75 (33)	19 (8)
Avoidance distance test	66 (24)	76 (28)	17 (15)
Qualitative Behavior Assessment	60 (37)	57 (20)	22 (11)

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Table 4: P-values of the univariate logistic regression models examining predictability of single measures for a herd to be categorized as 'Enhanced' or 'Not classified' based on the collated European dataset (n = 491)

Criteria, Measures	Enhanced	Not classified
Absence of prolonged hunger		
% of lean cows	<0.001	<0.001
Absence of prolonged thirst		
Number of water bowls	0.070	0.863
Water flow	<0.001	0.505
Trough length/cow (cm)	0.001	0.008
At least 2 drinkers/cow	<0.001	0.006
Drinker cleanliness	<0.001	0.068
Resting comfort		
Mean time needed to lie down	<0.001	0.577
% of cows colliding with housing	<0.001	0.365
% of cows lying outside of lying area	<0.001	0.014
% of cows with dirty flanks	0.101	0.172
% of cows with dirty lower legs	0.023	0.110
% cows with a dirty udder	0.374	0.258
Ease of movement		
Loose or tied housing	<0.001	0.016
Absence of injuries		
% of moderately lame cows	0.002	0.392
% of severely lame cows	<0.001	0.096
% of cows with at least one lesion/swelling	<0.001	0.014
% of cows with at least one hairless patch	0.141	0.075
Absence of disease		
Number of coughs/cow/minute	0.168	0.350
% cows with nasal discharge	0.092	0.165
% cows with ocular discharge	0.044	0.426
% cows with hampered respiration	0.293	0.385
% cows with diarrhea	0.386	0.546

% cows with vulvar discharge	0.588	0.936
% cows with SCC >400.000	0.130	0.014
% cows mortality	<0.001	0.189
% calvings with dystocia	0.619	0.841
% downer cows	0.742	0.423
Absence of pain induced by management procedures		
Method dehorning	0.130	0.021
Use of analgesics during/after dehorning	0.618	0.540
Use of anesthesia during dehorning	0.759	0.110
Method tail docking	0.150	0.974
Use of analgesics during/after tail docking	0.011	0.008
Use of anesthesia during tail docking	0.025	0.010
Expression of social behavior		
Head butts/cow/15 min.	0.033	0.759
Displacements/cow/15 min.	0.615	0.159
Expression of other normal behavior		
Number of hours on pasture	0.467	0.153
Number of days on pasture	0.810	0.454
Human-animal relationship		
% of cows that could be touched	0.711	0.188
% of cows that can be approached < 50 cm but not touched	0.012	0.379
% of cows that can be approached by 50 – 1 m	0.253	0.924
% of cows that can't be approached (> 1 m)	0.011	0.547
Positive emotional state		
QBA index score	0.079	<0.001

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Table 5: P-values and model estimates of measures in the multivariate logistic regression models predicting a herd to be categorized as 'Enhanced' or 'Not classified' based on the collated European dataset (n = 491)

Outcome variables	Enhanced model		Not classified model	
	Estimate	P-value	Estimate	P-value
Number of lean cows	-	-	1.8	<0.001
Water flow	1.1	<0.001	-	-
At least 2 drinkers/cow	2.4	<0.001	-3.7	0.007
Drinker cleanliness	0.6	<0.001	-	-
Mean time needed to lie down	-0.7	<0.001	-	-
% of cows lying outside of lying area	-0.9	<0.001	-	-
% of cows with at least one lesion/swelling	-0.5	<0.001	-	-
Number of displacements/cow/h.	-	-	0.7	0.043
QBA index score	-	-	-1.6	0.002

637 *Table 6: Systematic t-test P-value, Linear Regression R^2 and ICC of WQ integrated scores and trained*

638 *user median scores (n =14) for the focus herds (n = 7) for each WQ criterion*

Criteria	Median (IR)[1] WQ score	Median (IR)[1] expert score	Systematic t-test P-value	Regression R^2	ICC
Absence of prolonged hunger	67 (39)	50 (75)	0.475	0.237	0.6
Absence of prolonged thirst	20 (97)	50 (71)	0.737	0.007	0.7
Comfort around resting	27 (20)	25 (33)	0.181	0.880**	0.8
Freedom of movement	100 (33)	90 (90)	0.125	1.000***	1.0
Absence of injuries	28 (19)	18 (29)	0.006	0.926***	0.5
Absence of disease	40 (32)	42 (34)	0.296	0.903**	0.4
Absence of pain induced by management procedures	58 (18)	10 (50)	0.023	0.521*	0.8
Expression of social behavior	84 (24)	58 (50)	0.020	0.869**	0.6
Expression of other normal behavior	73 (78)	60 (78)	0.828	0.978***	0.9
Good human-animal relationship	54 (37)	52 (50)	0.023	0.984***	0.7
Positive emotional state	54 (32)	50 (37)	0.901	0.997***	0.8

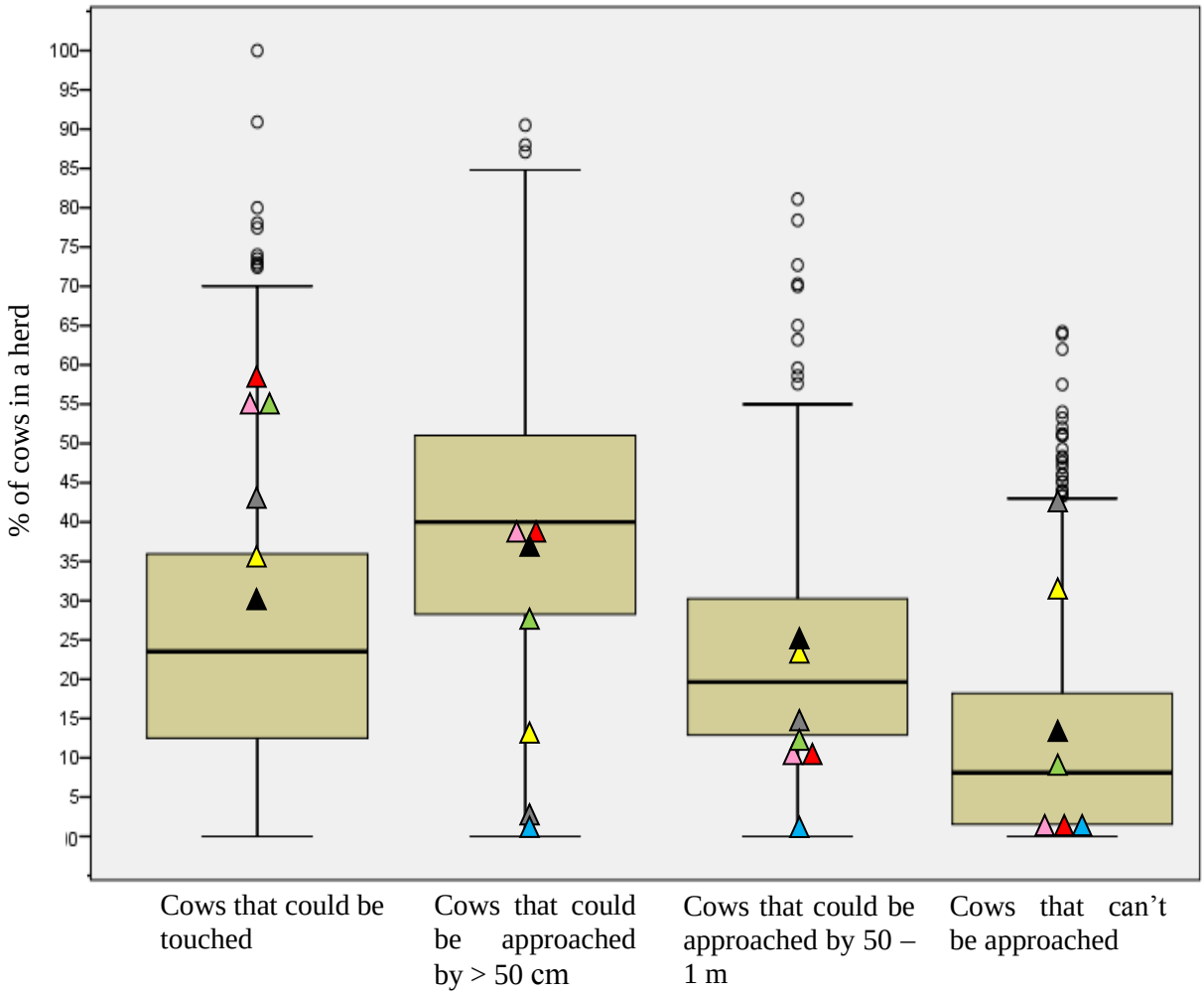
639 [1]IR = Interquartile Range

640 *P < 0.05

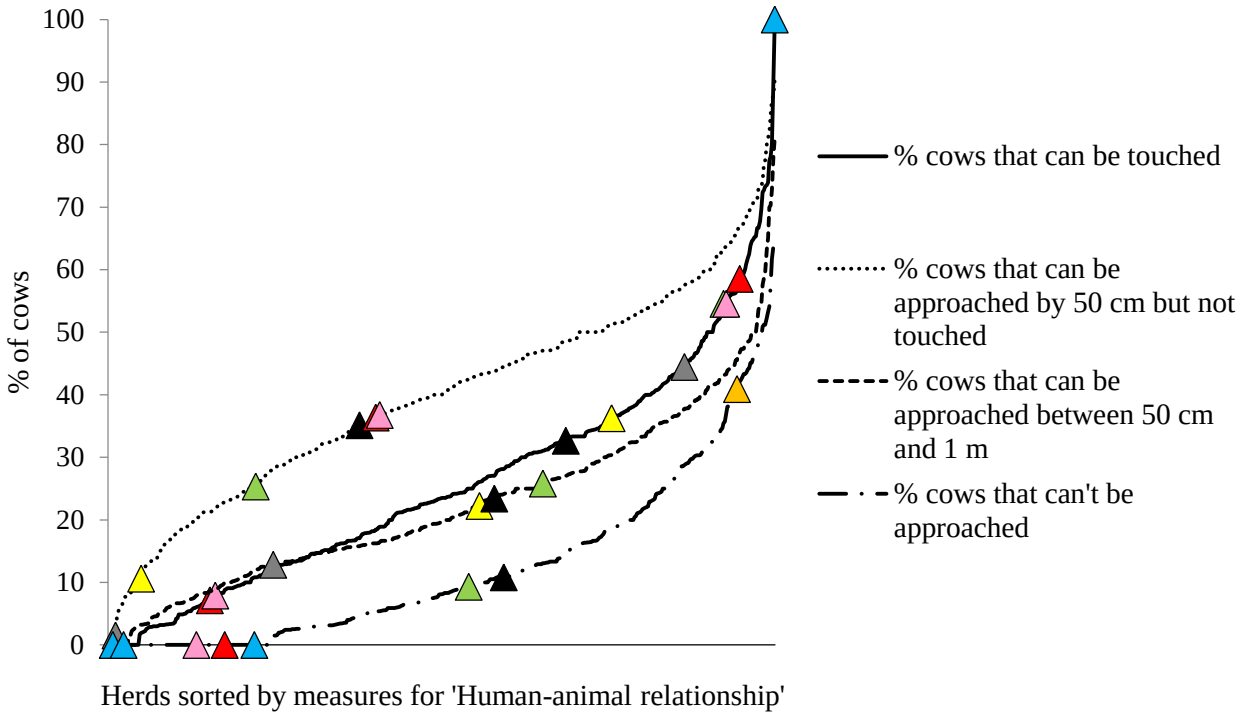
641 $^{**}P < 0.01$

642 $^{***}P < 0.001$

Figures



de Graaf, Figure 1



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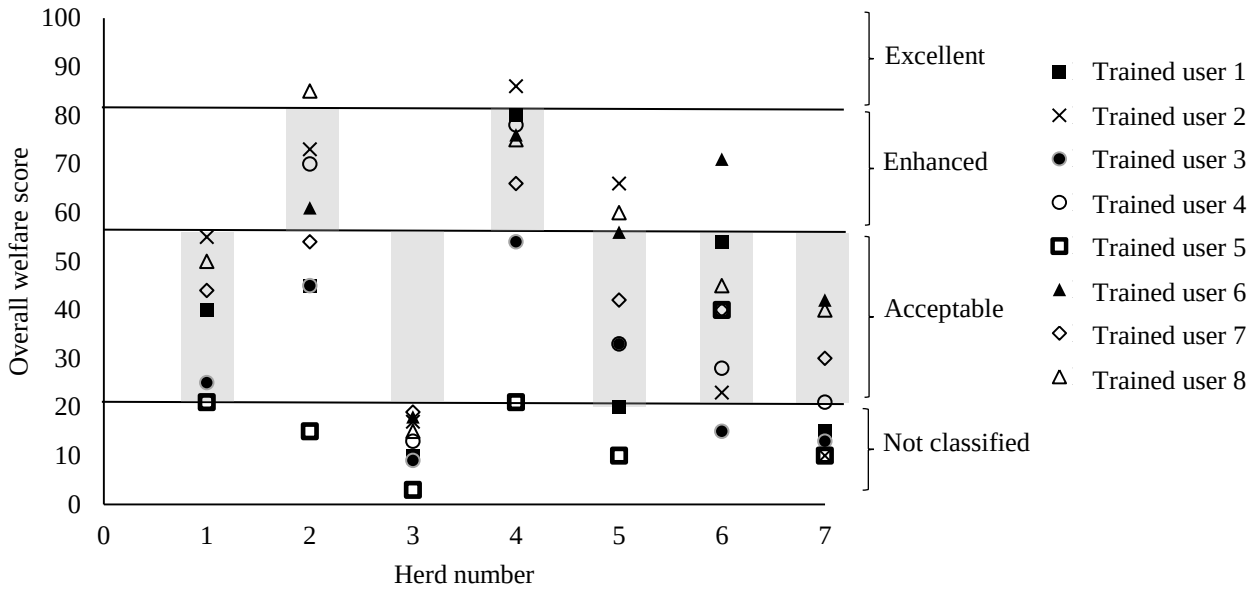
674 de Graaf , Figure 2



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676 de Graaf, Figure 3

Figure captions

Figure 1 Example boxplot figure from the survey among trained users, portraying the distribution of all herds in the database (n = 491) for the measures of the ADF, within the criterion 'Human-animal relationship'. Colored triangles mark the seven focus herds.

Figure 2 Example figure from the survey among trained users, portraying the distribution of all herds in the database (n = 491) for the measures of the Avoidance Distance at the the Feed rack test (ADF), within the criterion 'Human-animal relationship'. Colored triangles mark the seven focus herds.

Figure 3 Overall welfare score for all seven focus herds by eight trained users, grey boxes indicate WQ overall welfare category